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CREATING IMBALANCED THRUST IN A CENTER LINE MOUNTED MULTI-ENGINE JET AIRCRAFT CONFIGURATION AND A METHOD OF USING IMBALANCED THRUST

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BACKGROUND OF THE INVENTION

1. **<u>Cross-Reference to Related Patent Applications</u>**:

[0001] This patent application claims the benefit of U.S. Provisional Application No. 60/220,294, filed on July 24, 2000.

2. **<u>Field of the Invention</u>**:

[0002] This invention relates generally to multi-engine jet aircraft configurations, and more particularly to a centerline mounted unequal-thrust main engine configuration. The invention has particular utility for use in the business jet industry.

3. **<u>Description of the Related Art</u>**:

[0003] This invention is an improvement to the invention described in U.S. Patent Nos. 5,855,340 and 5,480,107 of Richard J. Bacon, both of which were invented by the inventor of this invention and are commonly owned by the assignee of this invention. Those patents are hereby incorporated by reference herein, and are referred to as the "prior patents."

SUMMARY OF THE INVENTION

[0004] This invention creates and uses imbalanced thrust (differential power) in a centerline mounted multi-engine jet aircraft. It includes: (a) a range of engine combinations, (b) a method of achieving or varying a thrust or power differential, (c) a range of operating methods, including sample profiles, (d) a number of particular applications, (e) improved design methods, and a number of other features and advantages, which are described both below and in the attachment

attached hereto comprising a cover sheet and pages A-1 through A-8 (the "Attachment"):

(a) A range of engine combinations.

[0005] Under the terminology of the prior patents, a 3X combination was discussed at some length. But surrounding the 3X range is a range produced by a wide variety of engine combinations. For example, a range of less than 2X to almost 4X (or beyond) may be employed. At the less-than-2X side, by focusing on the "cleaner" aerodynamics of the centerline mounted concept, with less drag than a conventional twin, and other advantages it may be possible to have a thrust equivalent to that of a conventional (2X-powered) twin while using engines of less actual thrust than the twin - - hence, a 1.6X (or even lower amount of combined thrust in a two-engine configuration) engine combination in accordance with the instant invention could equal the effective thrust of a conventional twin, and result in a lower initial purchase cost (because of the anticipated reduced cost in engine acquisition corresponding with the reduced thrust of the engines) while preserving the lower operating costs and increased engine-out safety of the centerline mounted concept.

(b) A method of achieving or varying a thrust differential in engines of the same size or different sizes.

[0006] The engine thrust differential may be achieved by various combinations of different engines. It may also be achieved by combinations of the same engines.

[0007] One way of achieving a thrust differential from a pair of engines which are the same is by "down-rating" or otherwise reducing an engine from its maximum thrust. It may be possible to purchase two engines of identical maximum thrust potential, but down-rate one of them

beneath its maximum thrust. Except for the down-rating, the engines are the same (resulting in common parts and common skills in the maintenance crew). Because of the down-rating, one of the engines (the down-rated one) may be less expensive than the other engine).

[0008] Even without down-rating, the benefits of a thrust differential could be achieved in a pair of centerline mounted engines which are entirely identical if one of them is either shutdown (that is, "staged") during one or more flight segments, or is run at a different power setting than the other engine.

(c) A range of operating methods.

[0009] By "staging" is meant shutting off one of the engines. As in the prior patents, the aircraft could be staged during taxi. But instead of staging during one or more of the flight segments (take-off, climb, cruise, descent and landing), both engines could be left running. Instead of staging during one or more of the flight segments, a thrust differential could be obtained by setting a pair of engines at different power settings, thereby creating an effective differential in thrust. This creation of differential thrust can be achieved without staging an engine, and it could even be achieved with identical engines. This leads to a wide range of operating profiles/operating methods.

[0010] A sample operational profile might be as follows:

	Engine (1)	*Engine (2)*
Taxi	off	operating

Takeoff & climb	operating	operating
Cruise & initial descent	operating	reduced power
Final descent & landing	operating	operating
Taxi	off	operating

[0011] Where the paired engines are of different size, engine (1) in the table above could be the larger of the two, and engine (2) in the table above could be the smaller of the two. By turning off the larger engine on taxi, and reducing the power of the smaller engine while in cruise and initial descent, operating costs are reduced.

[0012] This invention is not limited to the profile described in the table, but it should be understood that there is a large range of profiles. The concept of this invention permits the foregoing operational profile to be modified in every category to achieve whatever result is desired. For example, engines 1 & 2 could be the same size; the engine off on taxi could be engine 2; the engine reduced during cruise could be engine 1 (or both engines might be reduced on cruise); the reduction of power in one or both of the engines might be during cruise only, during cruise and initial descent, during final descent, or at any other time. A key concept is that the centerline thrust characteristics of a pair of main engines creates the room for developing unequal applications of thrust in order to achieve whatever level of higher performance (both engines operating), economy (one engine off, or one or both engines on reduced power), safety (both engines operating, though perhaps with one at reduced power - - in addition to the inherent

safety margin already provided in an engine-out emergency by a pair of engines having symmetrical, centerline thrust) or other advantage desired. Indeed, there are advantages to be gained even if the only staging or reduction in power occurs during taxi.

[0013] See also, examples 1-3 at pp. A-2 to A-4 of the Attachment.

(d) Particular applications.

[0014] This method can be used with any number of products, and may be adapted to a wide range of applications. Among the specific products appropriate for this concept are:

- a 19 passenger commuter (see attachment, p. A-7). It should be noted that the design of this product is intended to bridge the gap that presently exists between conventional turbo-prop aircraft in this category and a jet engine implementation.

- a utility jet (see attachment, p. A-7). It should be noted that the design of this product is intended to bridge the gap that presently exists between conventional turbo-prop aircraft in this category and a jet engine implementation.

- a fractional ownership aircraft (see attachment, p. A-6). It should be noted that the prior patents provide for staging, and the instant disclosure contemplates reductions in power in a non-staged profile.

- a relatively small, e.g., about 8,000 lb gross take off weight, or price target in the range

of about $1.0 to $2.5 million personal/business jet (see attachment, p. A-8). It should be noted that the design of this product is intended to bridge the gap that presently exists between conventional single engine aircraft in this category and a multiple jet engine implementation, as well as the gap between turbo-prop and jet engine implementations.

(e) Design methods.

[0015] As may be readily understood from the forgoing disclosures, this invention permits and encourages a new method of aircraft design. Rather than taking the necessity of identical engines as a given in any paired engine design, the freedom to create numerous combinations of differential thrust conditions (and then further to vary the thrust during operation of the aircraft) allows the designer the flexibility to solve problems and/or to maximize results in a new way. For example, the designer can target a particular product or niche (i.e., the 19 passenger commuter, the utility jet, the fractional ownership market, the small jet, or any other particular product); the designer can target any one or more of the typical criteria (acquisition cost, operational cost, speed, range/loiter, balanced field length, cabin volume, weight); and the designer can create the product which fulfills the need (that is, a concern with balanced field length might drive the size of the smaller engine; a concern with cruise speed might drive the size of the larger engine). Given an existing operating aircraft, the concept of this invention might permit a relatively rapid retrofit to enhance performance. Given a clean slate, the concept of this invention permits the designer rapidly to attain a concept-level design.

Advantages

[0016] By not requiring staging, this method can avoid staging issues - - that is, issues over whether an engine intentionally shut down during flight can be restarted "cold" when needed (and, therefore, it should not be necessary to obtain regulatory approvals, to obtain certifications or otherwise to satisfy the concern over whether an engine, once shut down during flight can be reliably counted upon to restart when needed). As understood from the foregoing discussion and as illustrated in the foregoing operational table, both engines can be kept running during flight, with one of them on reduced power.

[0017] Even without staging during flight, it is anticipated that this method can still reduce operating costs. The applicant has estimated that the staged method of the prior patents might result in about a 30% savings in operating costs. The applicant is estimating that the non-staged method (that is, no staging during flight, but with staging on taxi and reduced power in flight) discussed above can still yield about a 20% savings in operating costs.

[0018] The method described above continues to preserve the safety of centerline thrust in an emergency engine-out condition (because of the symmetrical thrust) as compared to the emergency engine-out condition in a conventional twin (with asymmetrical thrust).